KW: amphib, hell, thesis

STATUS OF THE EASTERN HELLBENDER (*CRYPTOBRANCHUS ALLEGANIENSIS ALLEGANIENSIS*) IN MISSOURI: A COMPARISON OF PAST AND PRESENT POPULATIONS

- Canoe floating to 22 potential sampling sites
- loss of size classes over time (does [illegible] as [illegible])

A Thesis
Presented to
the Graduate College of
Southwest Missouri State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Ethan Prosen
July 1999

STATUS OF THE EASTERN HELLBENDER (*CRYPTOBRANCHUS ALLEGANIENSIS ALLEGANIENSIS*) IN MISSOURI: A COMPARISON OF PAST AND PRESENT POPULATIONS

Department of Biology

Southwest Missouri State University, July 1999

Master of Science

Ethan Prosen

ABSTRACT

Eastern hellbenders, *Cryptobranchus alleganiensis alleganiensis*, were collected from the Big Piney, Gasconade, and Niangua Rivers. Total length and mass measurements were taken for comparison with historical data from the same rivers. There have been substantial declines in the numbers of hellbenders captured from each river. Hellbenders from the 1998 samples were larger on average than historical individuals. This increase in size appears to be due to reduction of smaller size classes. Average body conditions have changed, but not consistently. More work is needed to determine the status of hellbenders is Missouri.

This abstract is approved as to form and content

S. Alicia Mathis

Chairperson, Advisory Committee
Southwest Missouri State University

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ACKNOWLEDGMENTS

I would like to thank my committee members: Alicia Mathis, Robert Wilkinson, and Brian Greene for their aid and advice. I am especially thankful to Dr. Mathis for her aid in data analyses. I am grateful for the field assistance of Robert Wilkinson, Chris Peterson, Ben Wheeler, Aaron Sullivan, Paul Frese, and all the other graduate students who helped collect hellbenders and record historical data.

Financial support was provided by Southwest Missouri State University and by a grant from the Missouri Department of Conservation. I would like to thank the Graduate College for additional financial support.

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INTRODUCTION

During the first International Herpetological Congress, held in Canterbury England in 1989, many researchers from around the world reported declines in amphibian study populations (Wyman, 1990). The declines appear to have begun almost simultaneously across the globe in the 1970's (Barinaga, 1990). However, some of the declining populations, such as the golden toad (*Bufo periglenes*) of the Monteverde cloud forest in Costa Rica and the gastric brooding toad (*Rheobatrachus silus*) of Australia, are in "pristine" areas (Blaustein and Wake, 1990). The main cause of decline in amphibian populations is habitat destruction (Griffiths and Beebee, 1992; Walls et al., 1992). There is no apparent single global cause for declines not directly related to habitat destruction. Declining and non-declining populations can co-occur making determination of causes more difficult.

The declines of amphibian populations are a cause for concern for two major reasons. First, amphibians are important as both predator and prey in many habitats, so decreases in amphibian populations may have wide ranging effects across the food web. The biomass of salamanders in the Hubbard Brook experimental forest, New Hampshire, is greater than that of birds during peak breeding season and approximately equals that of mice and shrews (Burton and Likens, 1975). Second, Amphibians have moist permeable skin (Duellman and Trueb, 1994), which provides little barrier to harmful agents in their environment (Barinaga, 1990; Blaustein and Wake, 1990). Moreover, many taxa have complex life cycles with both aquatic and terrestrial phases (Duellman and Trueb, 1994), providing them with wide-ranging opportunities for exposure to those agents. Because of these characteristics amphibians may be good indicators of habitat degradation (Phillips, 1990; Wake 1991). The amphibian declines may represent the first stage of a declining ecosystem (Barinaga, 1990; Wyman, 1990).

Beyond the obvious influence of habitat destruction, amphibian declines may be caused by global climatic change, pollution, ultraviolet radiation, and habitat fragmentation (Wyman, 1990). Apparent regional and species-specific effects complicate determination of the cause of amphibian decline. Urbanization of Tampa Palms, Florida appears to have eliminated four species of frog from the area, but some species are doing better within the urbanized areas (Delis et al., 1996). Carey (1993) suggests that environmental stresses coupled with low temperatures could suppress amphibian immune systems leading to increased disease. Current levels of UV light do not appear to be high enough to be the lone causative factor (Licht and Grant, 1997). However, "normal" levels of UV-B radiation do adversely affect salamander egg survival (Blaustein et al., 1995) and there is a correlation between UV resistance and population status in field studies of anurans (Blaustein et al., 1994b). A pathogen appears to be the causative factor in anuran decline in North Queensland (Trenerry et al., 1994). Pechmann et al. (1991) found that the declines in species studied at Rainbow Bay, South Carolina could be explained as natural fluctuations.

One major problem in the debate about amphibian declines is the lack of long term studies. One possible explanation of the apparent decrease in amphibian populations is that the decrease is the result of natural population cycles (Pechmann et al., 1991). Most amphibian studies last only a few years and none last more than one or two turnovers of the study population (Blaustein et al., 1994a). The natural amount of long term fluctuation in amphibian populations has not been well documented and it is possible that cyclical declines may not be unusual (Pechmann and Wilbur, 1994). However, Pounds et al. (1997) found that amphibian declines in the Monteverde cloud forest of Costa Rica were greater than expected by chance and amphibian declines were greater than the decline in birds during the same five-year period. Long term studies are essential to determine whether amphibian populations are suffering unusual declines (Blaustein et al., 1994a). This study examines long-term (20+ years) changes in population characteristics of one species of salamander, the hellbender (*Cryptobranchus alleganiensis alleganiensis*).

The salamander family Cryptobranchidae has two living genera: *Andrias*, which lives in Asia and Japan, and *Cryptobranchus*, which lives in the central and eastern United States. *Cryptobranchus* has one species, *C. alleganiensis*, with two subspecies: *alleganiensis* and *bishopi* (Nickerson and Mays, 1973). The eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*) is native from southern New York to northern Georgia west through Tennessee and the Ohio River Valley and in north flowing rivers of Missouri (Nickerson and Mays, 1973; Peterson et al., 1989). Eastern hellbenders in Missouri are found in the Big Piney, Gasconade, Meramec, and Niangua rivers. Outside of Missouri, eastern hellbenders have been found in the Little Pigeon river in Tennessee (Fitch, 1947), Big Walker Creek in Virginia (Fauth et al., 1996), the

New York portion of the Susquehanna river drainage (Soule and Lindberg, 1994), and the Wabash river of Illinois (Brandon and Ballard, 1994).

Hellbenders have dorso-ventrally flattened bodies with laterally compressed tails. They are covered by a loose wrinkly skin, forming folds along the sides of the body and posterior sides of the limbs. They have large mouths and small eyes, and are a dull brown with conspicuous black spots and less conspicuous yellow spots scattered across the dorsal and lateral surfaces. Older animals tend to be a greenish or reddish brown (Smith, 1907).

Hellbenders are habitat specialists preferring shallow, swift-flowing water with rocky bottoms (Hillis and Bellis, 1971; Smith, 1907; Williams et al., 1981). The rocky bottoms provide ample diurnal hiding places for these primarily nocturnal animals (Fobes, 1995; Smith, 1907). Hellbenders use both pulmonary and cutaneous respiration (Nickerson and Mays, 1973), but primarily respire cutaneously (Guimond and Hutchison, 1973). Cold swift-moving water is an important habitat requirement, possibly because it carries more oxygen, allowing more efficient cutaneous gas exchange (Guimond and Hutchison, 1976).

With their cryptic coloration, hellbenders appear to be sit-and-wait predators, and large rocks may be important resources because they provide sites from which prey can be ambushed. Their primary prey are crayfish (Smith, 1907) with small fish rating second (Peterson et al., 1989). These two taxa combined make up approximately 90 percent of the diet of hellbenders (Peterson, et al., 1989). Snails and other small aquatic invertebrates are occasionally eaten (Peterson et al., 1989; Wiggs, 1976), and hellbenders sometimes eat the eggs of conspecifics (Smith, 1907).

Hellbenders grow rapidly as juveniles and more slowly as they get older (Peterson et al., 1983; Taber et al, 1975) and populations are dominated by older, larger individuals (Peterson, 1979). Hellbenders metamorphose at about 18 months of age at a total length (TL) of about 125mm (Bishop, 1941). Males and females grow at similar rates (Peterson et al., 1983), although females tend to be slightly larger at a given length (Taber et al., 1975). Mean growth rates indicate longevity exceeding 20 (Peterson, 1979) to 30 years (Taber et al., 1975).

Hellbender home ranges vary in size and overlap. Hillis and Bellis (1971) found hellbender home ranges to be approximately 100-200 m^2. Coatney (1982) found mean home range sizes of about 99 m^2 for females and 83 m^2 for males. Peterson and Wilkinson (1996) found average home range sizes of 28 m^2 for females and 81 m^2 for males. The same rock can be used as a shelter by several different individuals, although not at the same time. Active defense appears limited to a shelter defense. More than one hellbender is rarely found under the same rock, except when they breed in the late summer through early winter (Peterson and Wilkinson, 1996).

During the breeding season, hellbenders congregate during the day in groups of six to twelve (Smith, 1907). Fertilization is external; the female deposits the eggs in the

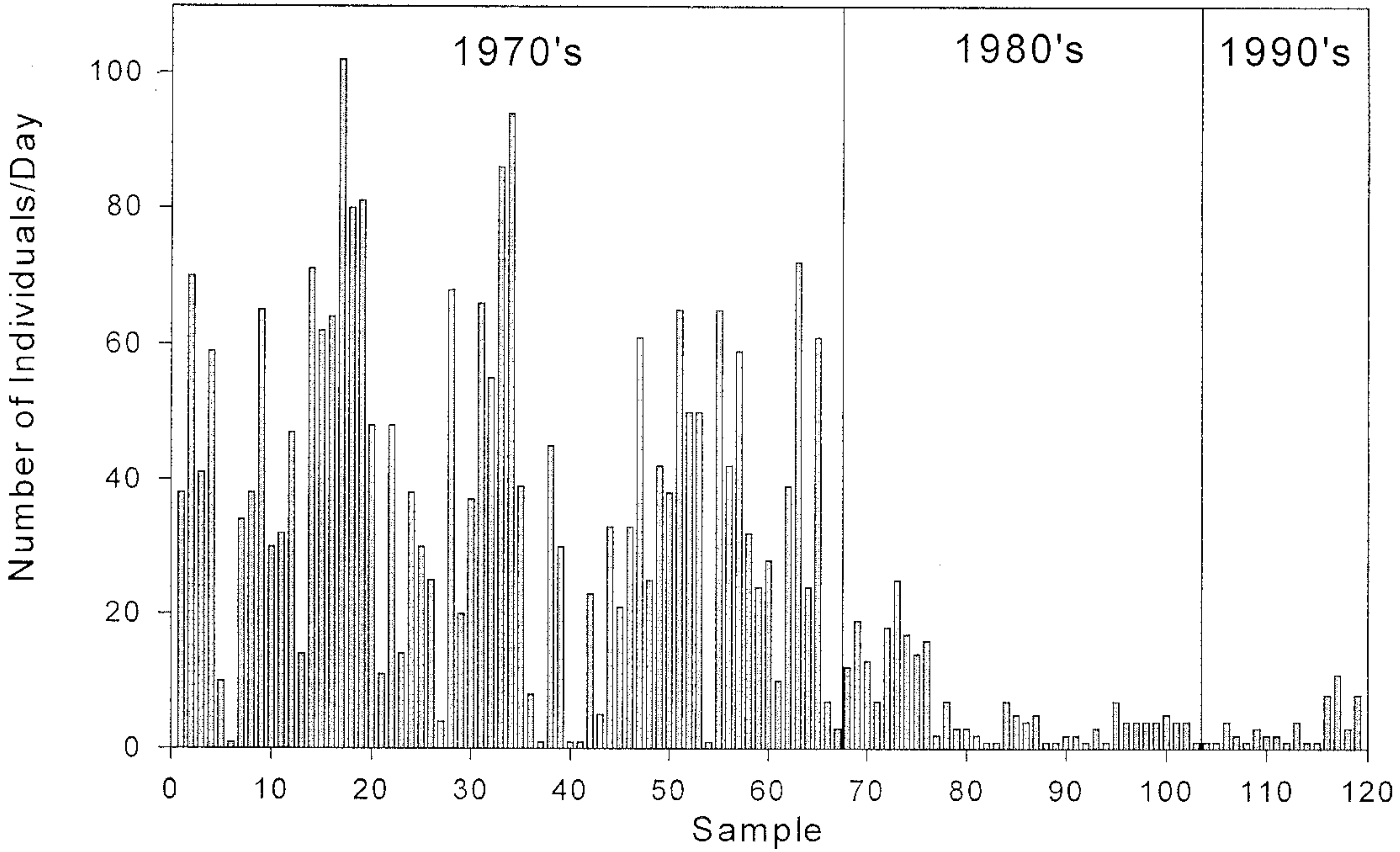

Fig 3: Comparison of total number of individuals captured per day in the Niangua River for all studies from which data were available. No statistical comparison was made.

nest, either under a cover object, such as a large rock (Smith, 1907) or in a crevice in the river's bank (Nickerson and Tohulka, 1986). The male remains with the eggs providing protection, but it is uncertain whether the male is directly protecting the eggs or defending the nesting spot for another female (Smith, 1907).

Hellbenders are endangered and the major threat is the disruption of their habitat (Williams et al., 1981). Hellbenders are experiencing rapid shrinkage of their range in the Ohio and the lower Wabash valleys due to human modification of stream habitats (Smith and Minton, 1957). Dynamiting large boulders out of rivers to save canoe renters money may reduce the number of hellbender nesting sites in Missouri (Nickerson and Mays, 1973).

Extensive data on age structure, body condition, and distribution were collected in the 1970's and 1980's (Merkle et al., 1977; Peterson, 1987; Peterson et al., 1988; Taber et al., 1975). I sampled the same rivers that were previously censused and compared data from 1998 to the historical data. Specifically, I compared data for 1998 and historical populations with respect to (1) density, (2) size distributions, and (3) body condition. Comparisons between recent and past populations of hellbenders in Missouri will assist in development of conservation methods and may help shed some light on amphibian declines.

METHODS

Eastern hellbenders were sampled from the Big Piney, Gasconade, Meramec, and Niangua rivers from May through September 1998. Each river was floated by canoe and/or spot-checked by driving to river access points. All "likely" (Fobes, 1995) sites were sampled for hellbenders; a likely spot was defined as a shallow, 1-2 meter deep, section of river with a rocky bottom and swift current. There were 13 sample sites in the Big Piney between Boiling Springs and Rennick's Resort. The Gasconade River was sampled 30 times between Hartville and Jones Creek. The Meramec River was sampled 10 times between the Missouri Department of Conservation (MDC) Woodson K. Woods Wildlife Area access and the MDC Riverview public access. The Niangua River was sampled 20 times between Bennett Spring and Bird Island, slightly upstream of Lake Niangua. I took care to sample the same sites as previous studies when possible, but in many cases previous sample sites had become unsuitable because the bottom of that section of river had been silted in or the riffle had become a pool.

upstream | downstream

At each site, the upstream ends of rocks were rolled slowly with the collector positioned downstream. Masks were used to aid visibility. Exposed hellbenders were caught by hand and placed in mesh bags. Each individual was measured for total length (TL) to the nearest millimeter on a standard fish board and mass to the nearest gram using an Ohuas LS2000 portable electronic balance. Individuals were not anesthetized because stress resulting from the measuring technique was minimal. TL was used because there is a linear relationship between snout-vent length and TL in hellbenders and it is more precisely obtained, due to the shape of the animals (Taber et al., 1975). The bulk of a

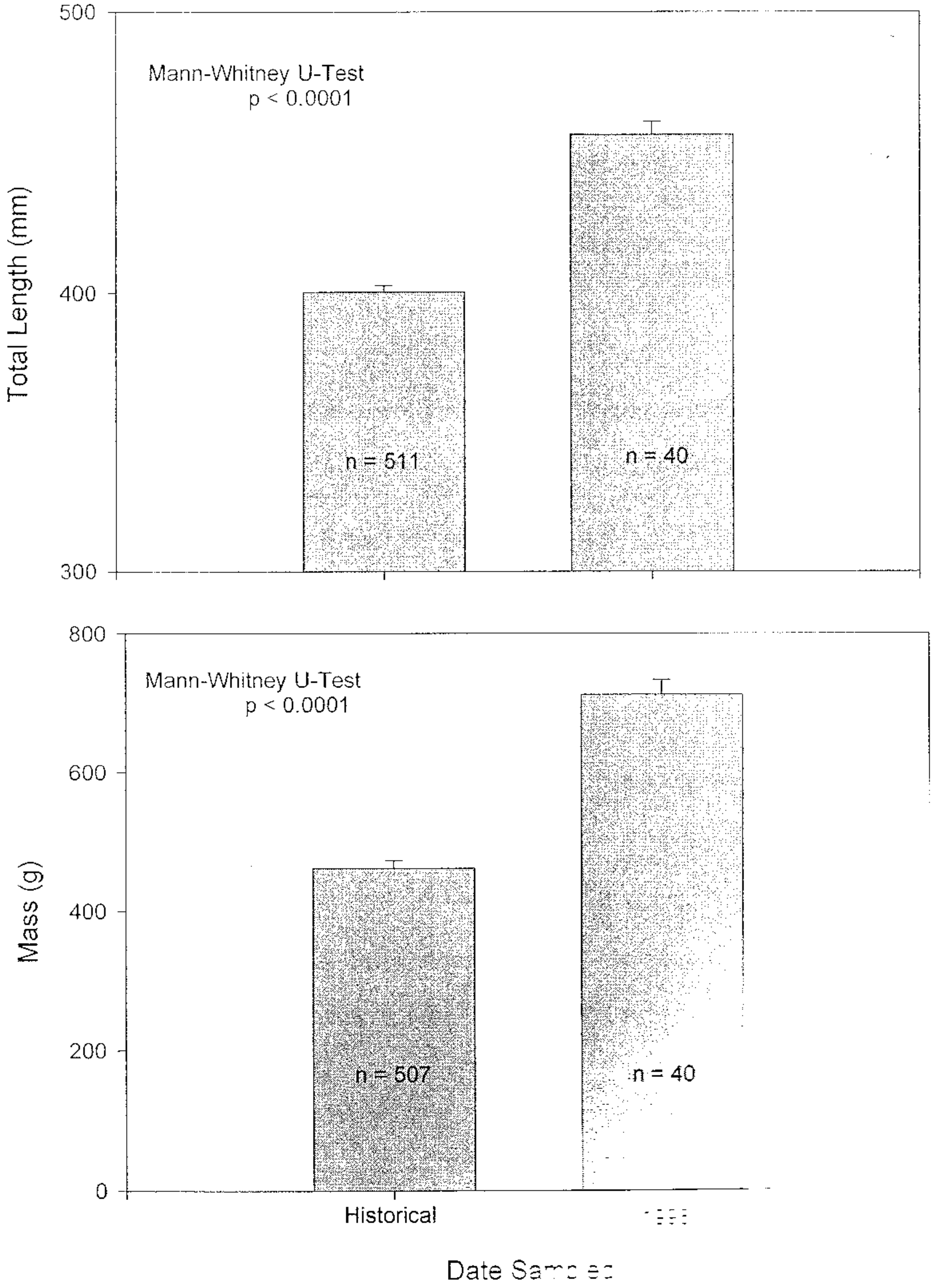

Fig 4: Comparison of mean total lengths and masses of [illegible] from both 1998 and historical samples. Historical data were taken in 1978, 1980, 1981, and 1982 [illegible]

hellbender makes it difficult to measure snout-vent length unless the animals are lain on their backs which conscious hellbenders resist strongly. Sex was determined when possible (during the breeding season); males have a swollen ring around the cloaca and females have a swollen abdomen (Nickerson and Mays, 1973). Individuals were released unharmed at the site of capture. Individuals were not marked in this study to save time and because I did not anesthetize the animals captured.

Historical data (length, mass, and sex) were taken from the records of Robert Wilkinson and Chris Peterson (pers. comm.). Table 1 summarizes time and location of historical data.

Table 1: Time and location of historical data

River	Date
Big Piney	1978, 1980, 1981, 1982
Gasconade	1978, 1980, 1981, 1982
Meramec	None
Niangua	1971, 1972, 1973, 1979, 1980, 1986, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1997

Each individual was included only once in the data analyses to maintain statistical independence. Individuals from the historical data set recaptured in 1998 were only included in the 1998 sample. Data for mass were not available for some individuals in the historical data sets.

Body condition was based on measurements of length and mass. The cubed root of mass was regressed against TL for all hellbenders. The cubed root of mass was used instead of mass to standardize variances and create a more linear relationship between length and mass. The resulting residuals were then compared between historical and 1998 samples. Only males were used for the body condition calculations because TL to mass ratios for females change when they produce eggs during the breeding season.

Data for each river were analyzed separately. Non-parametric tests were used for most statistical comparisons because the 1998 data failed to meet assumptions of parametric statistics. Historical and 1998 mean lengths and masses were compared using Mann-Whitney U-tests. Kolmogorov-Smirnov tests were used to compare historical and 1998 length frequency distributions. Body conditions were compared using Mann-Whitney U comparisons of the residuals from regressions for recent and historical males. Regressions and Mann-Whitney U-tests were performed using MINITAB software. Kolmogorov-Smirnov tests were performed by hand using formulas from Sokal and Rohlf (1995). All statistical tests were two-tailed. The Meramec River was not used in these analyses because of small sample size (n = 2).

individuals (Mann-Whitney U-test: W = 131744.5, p < 0.0001, Fig. 4). The size class distributions were significantly different, with relatively fewer individuals in the smaller size classes (Kolmogorov-Smirnov: D = 0.4567, p <0.0001, Fig. 5). Males from the 1998 sample were in better condition than historical males (Mann-Whitney U-test: W = 10388.0, p = 0.0001, Fig. 6).

Gasconade River

Of the 33 hellbenders captured in 1998, 10 individuals had legible brands from 1980 to 1981, and three others were branded previously but the numbers were illegible. The mean length of 1998 individuals was greater than that of the 379 historical individuals (Mann-Whitney U-test: W = 75800.0, p = 0.0002, Fig. 7). The mean mass of 1998 individuals also was greater than that of 351 historical individuals (Mann-Whitney U-test: W = 65458.5, p = 0.0005, Fig. 7). The size class distributions were significantly different, with relatively fewer individuals in the smaller size classes (Kolmogorov-Smirnov: D = 0.3104, p =0.0058, Fig. 8). Although there was no significant difference between the body conditions of 1998 and historical males (Mann-Whitney U-test: W = 8066.0, p = 0.6206, Fig. 9), the statistical power of this comparison is low due to the small number of 1998 animals (n = 8).

Niangua River

Initial analyses used three data sets: 1970's (1971, 1972, 1973, 1974), 1980's (1979, 1980, 1986, 1988, and 1989) and 1990's (1990, 1991, 1992, 1993, 1994, 1997, and 1998). There was a significant difference between groups for TL (Kruskal Wallis:

RESULTS

Density

Population densities could not be compared statistically because some historical sites no longer contained suitable habitat and catch-per-unit effort could not be standardized. The number of people collecting on a given day ranged from two to ten historically and was usually four in 1998. Collection times ranged from thirty minutes to two hours at each site for both historical and 1998 surveys. Qualitatively, 1998 surveys yielded substantially fewer hellbenders than historical surveys. This apparent decline was consistent for all populations (Table 2).

TABLE 2: Total number of individuals captured

River	1970's	1980's	1990's
Big Piney	---	511	40
Gasconade	---	379	33
Niangua	1225	125	52

The numbers of individuals captured per day also indicate decreases over time (Figs. 1, 2, and 3). Although this analysis controlled for difference in number of sampling days, it does not control for possible differences in catch-per-effort. Therefore, these data also are presented only for purpose of qualitative comparisons.

Size and Body Condition

Big Piney River

Forty individuals were captured in 1998; one had a legible brand from 1980 and was deleted from the 1980 sample. The mean length of 1998 individuals was greater than that of 511 historical individuals (Mann-Whitney U-test: $W = 134111.0$, $p < 0.0001$, Fig. 4). The mean mass of the 1998 individuals was greater than that of 507 historical

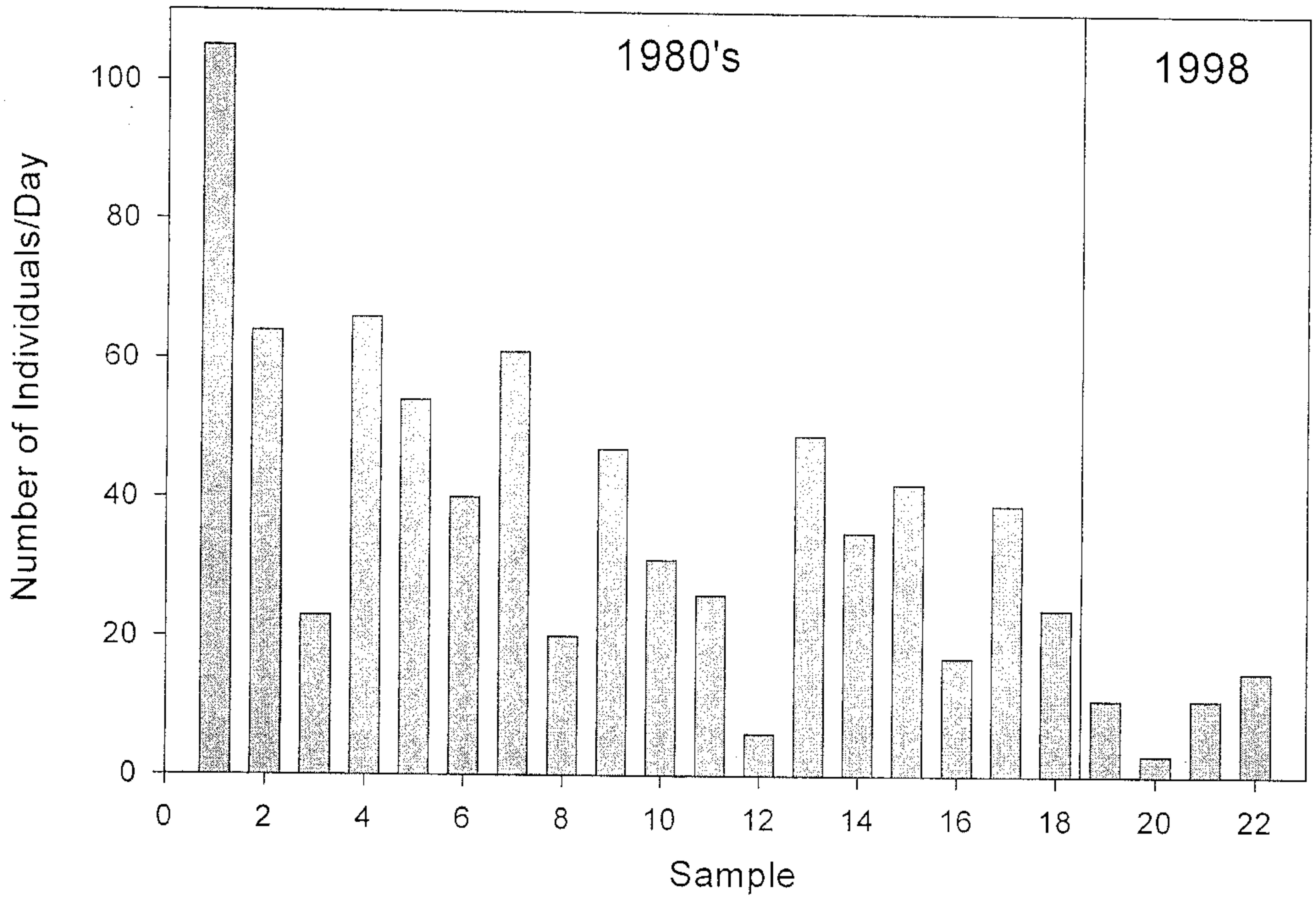

Fig 1: Comparison of total number of individuals captured per day in the Big Piney River for all studies from which data were available. No statistical comparison was made.

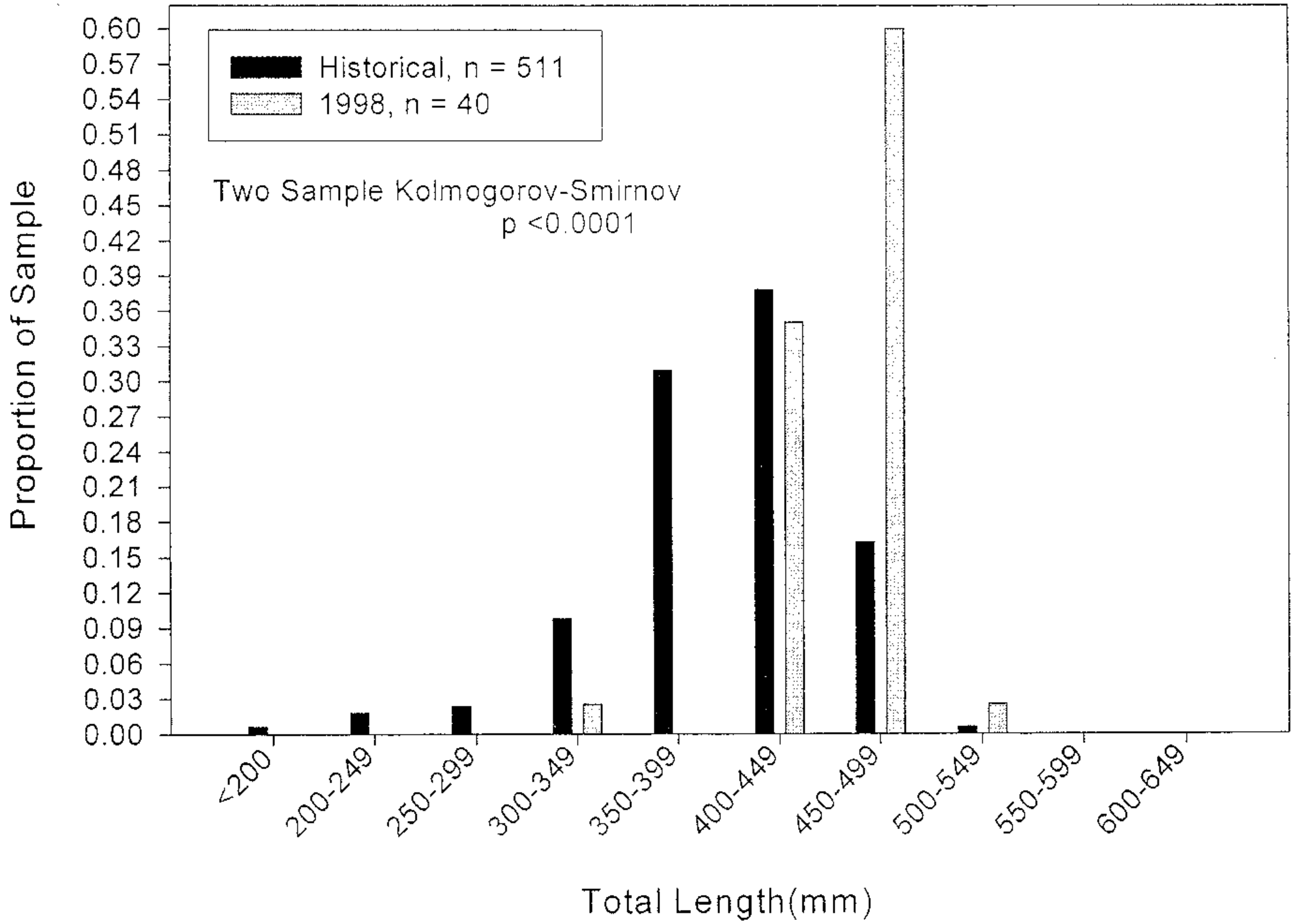

Fig 5: Comparison of size distributions of 1998 and Historical samples from the Big Piney River Historical sample from 1978, 1980, 1981, and 1982. Bars show proportion of sample in each size class.

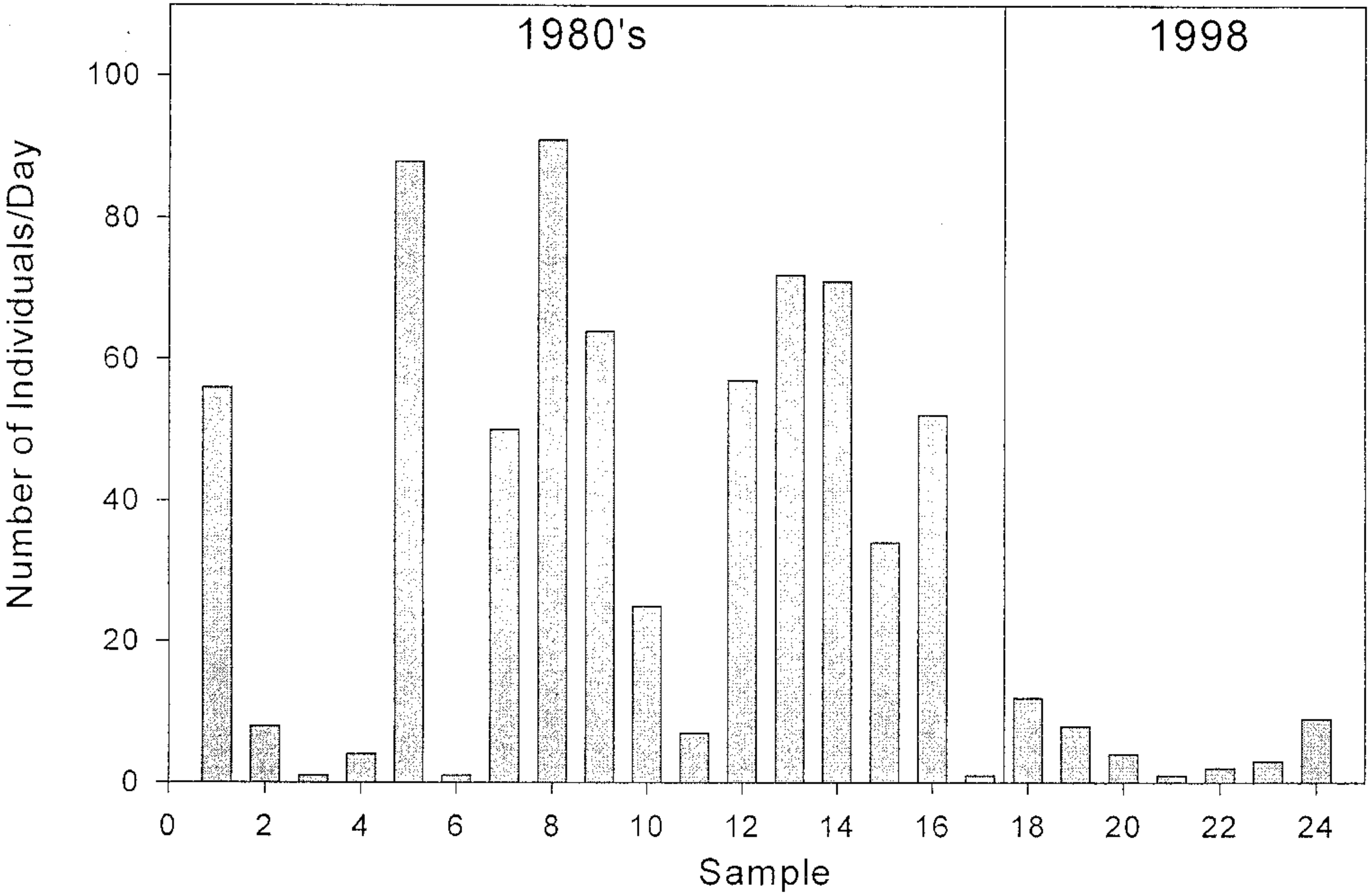

Fig 2: Comparison of total number of individuals captured per day in the Gasgonade River for all studies from which data were available. No statistical comparison was made.

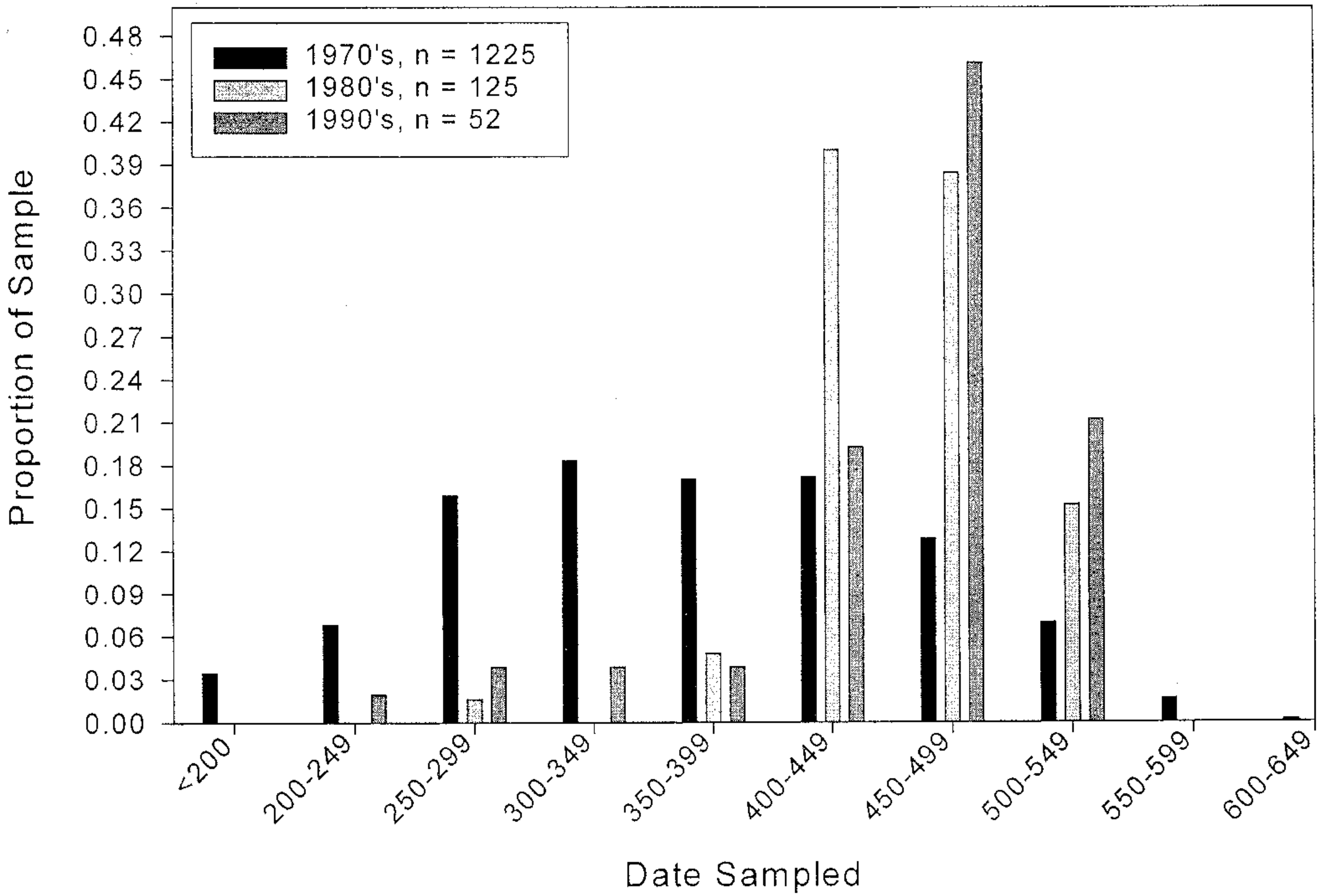

Fig 11: Comparison of size distributions of 1970's, 1980's and 1990's samples from the Niangua River. Bars show proportion of sample in each size class.

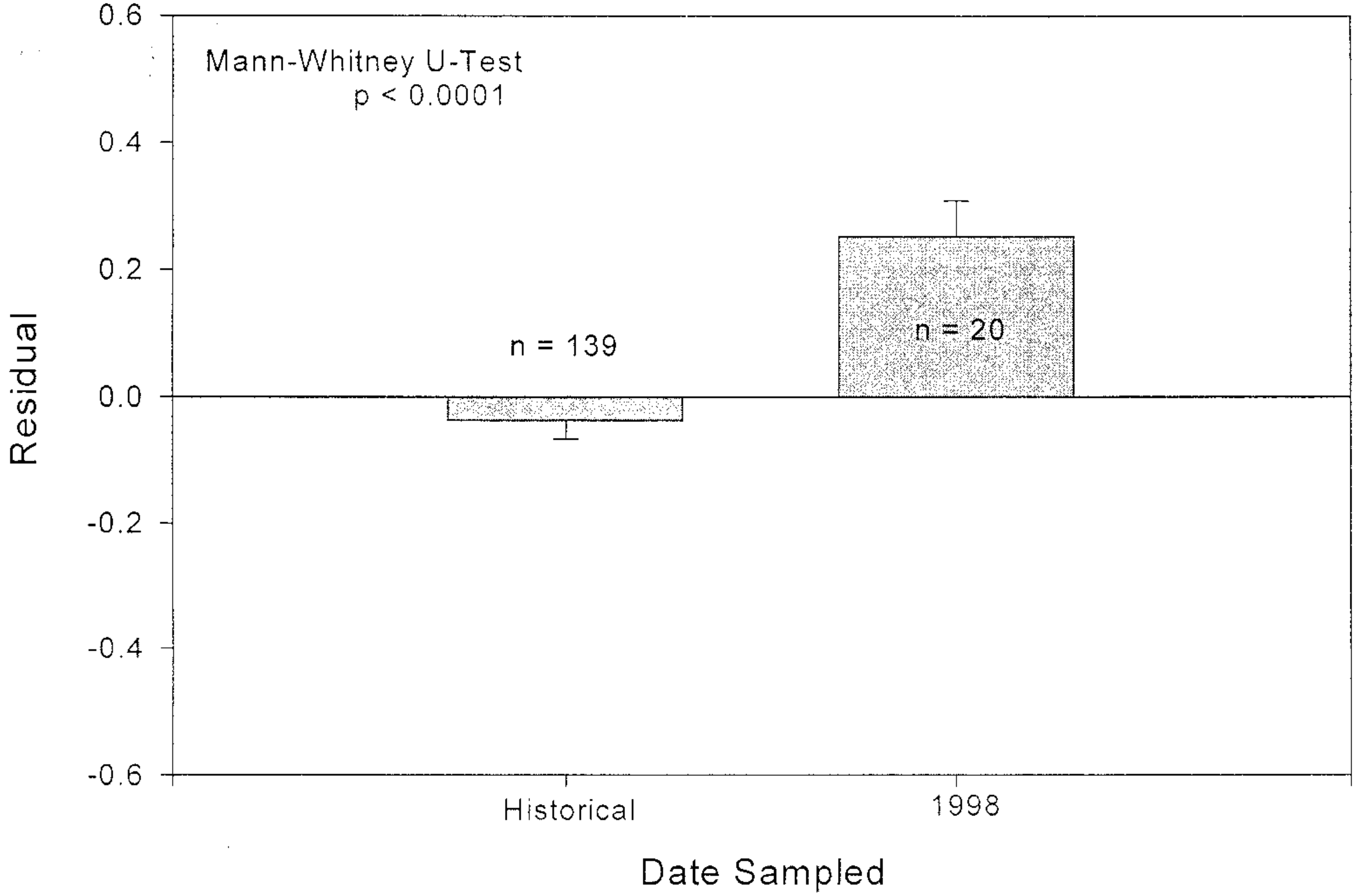

Fig 6: Comparison of body condition residuals of male hellbenders in the Big Piney River from historical and 1998 samples. Historical samples were taken in 1978, 1980, 1981, and 1982. Bars show means ±1 SE.

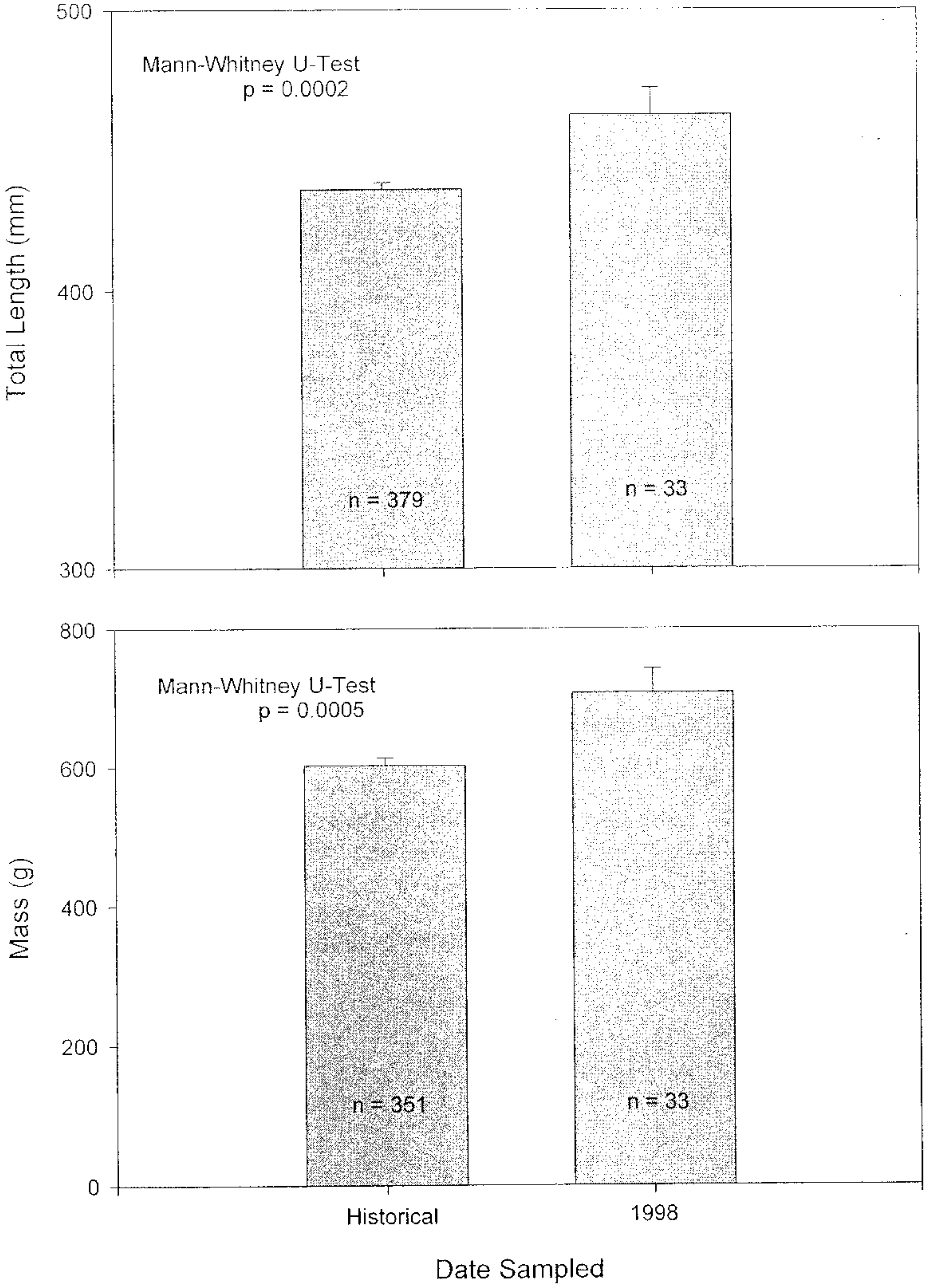

Fig 7: Comparison of mean total lengths and masses of hellbenders in the Gasconade River from both 1998 and historical samples. Historical samples were taken in 1978, 1980, 1981, and 1982. Bars show means ±1 SE.

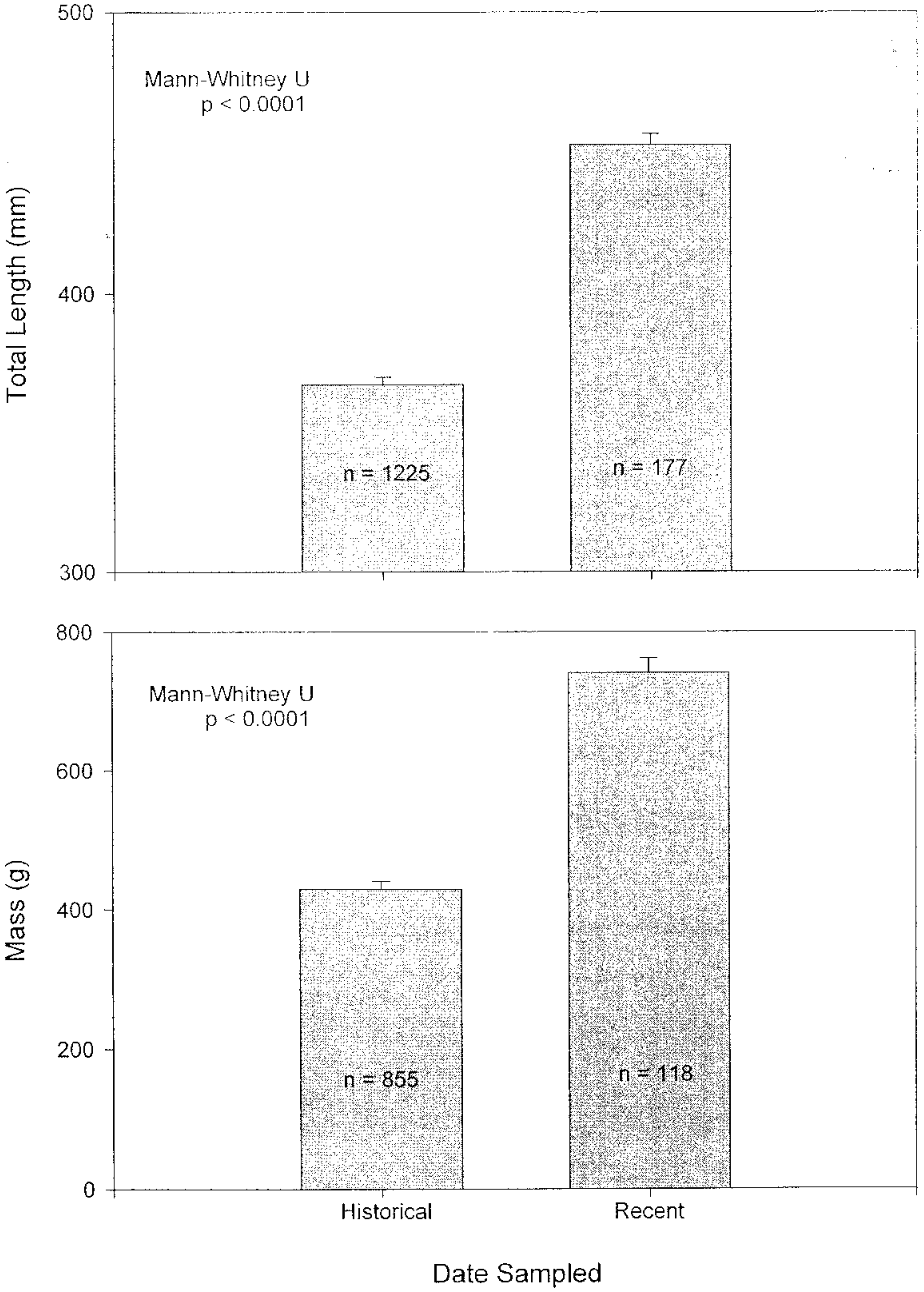

Fig 12: Comparison of mean total lengths and masses of hellbenders in the Niangua from samples taken both historically and in the 1990's. Historical data were taken in 1971, 1972, 1973, and 1974. Recent data for lengths were taken in 1979, 1980, 1986, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1997, and 1998. Recent data for mass were taken in 1980, 1988, 1990, 1991, 1992, 1993, 1994, 1997, and 1998. Bars show means ±1 SE.

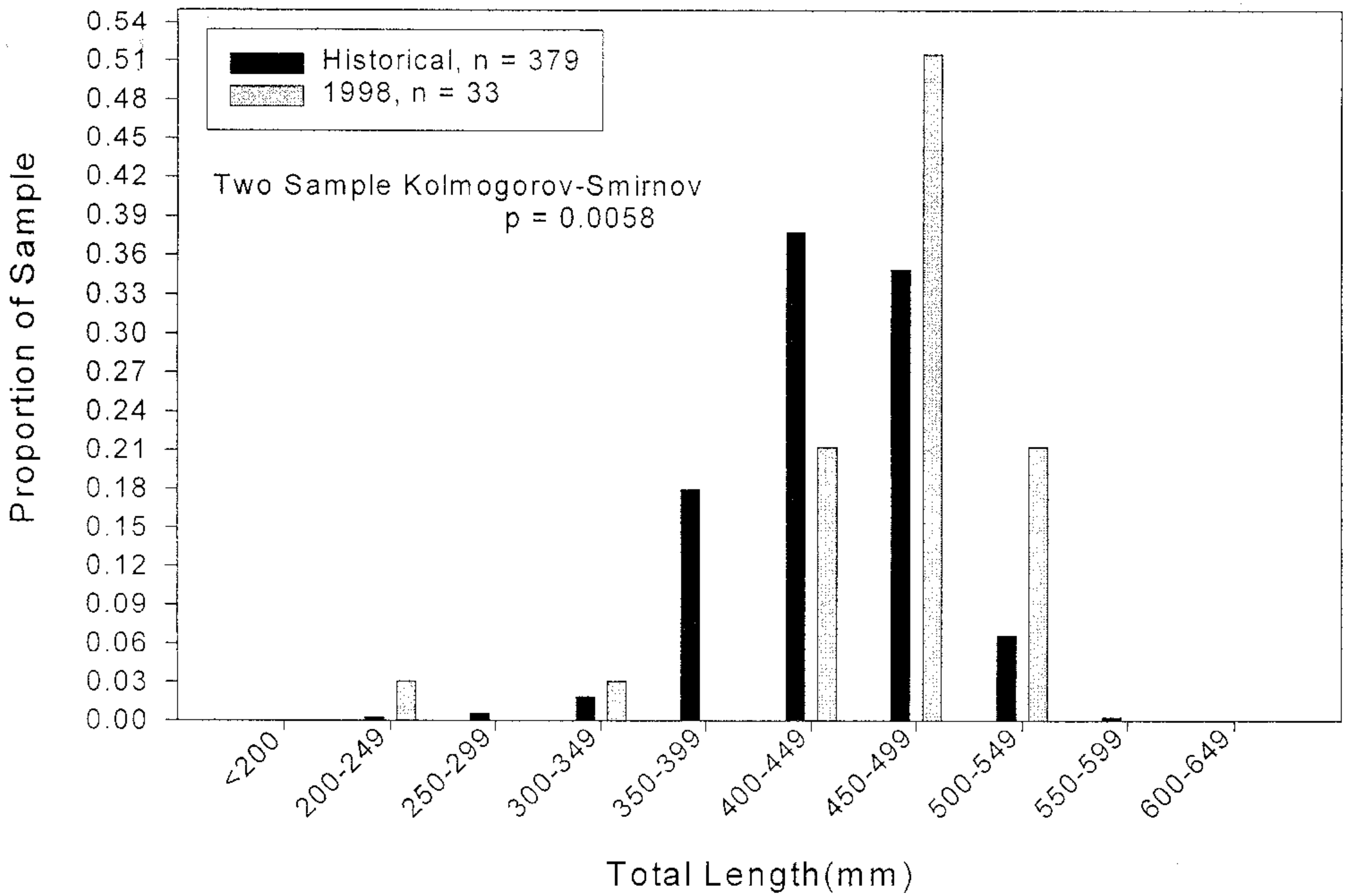

Fig 8: Comparison of size distributions of 1998 and Historical samples from the Gasconade River Historical samples were from 1978, 1980, 1981, and 1982. Bars show proportion of sample in each size class.

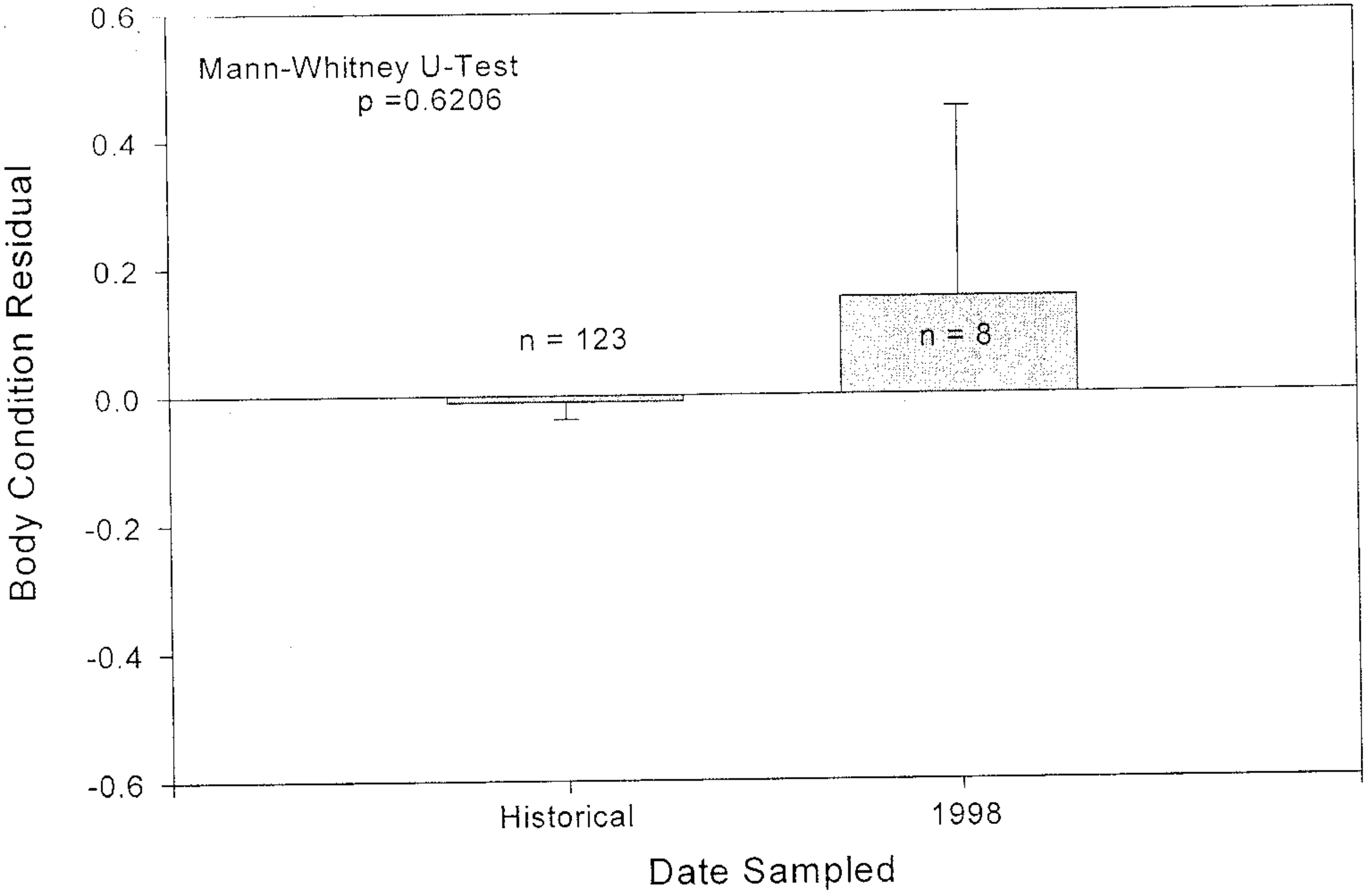

Fig 9: Comparison of the residuals of the body conditons of male hellbenders in the Gasgonade River from historical and 1998 samples. Historical data were taken in 1978, 1980, 1981, and 1982. Bars show means ±1 SE.

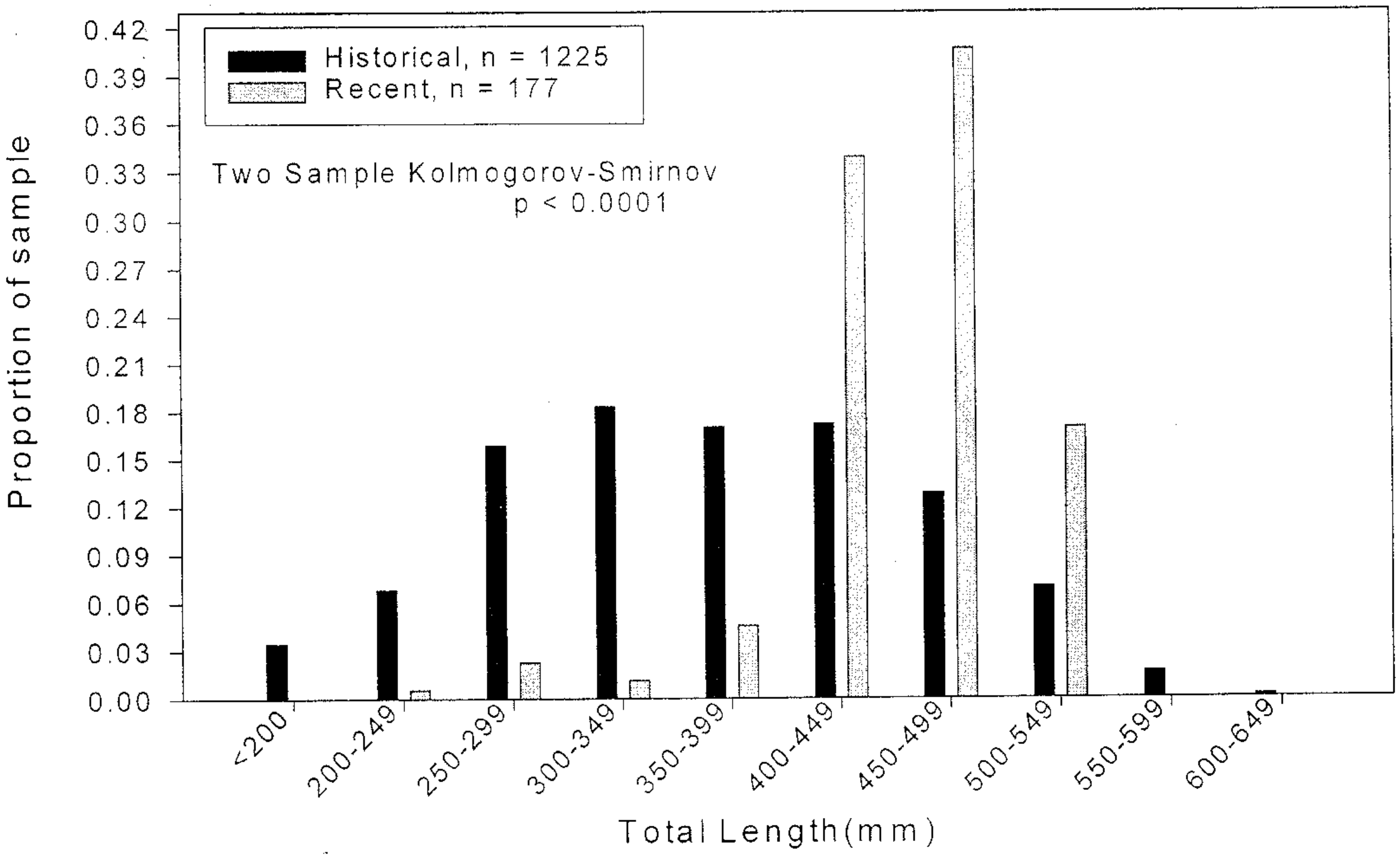

Fig 13: Comparison of size distributions of recent and historical samples from the Niangua River. Historical samples were from 1971, 1972, 1973, and 1974. Recent samples were taken in 1980, 1988, 1990, 1991, 1992, 1993, 1994, 1997, and 1998. Bars show proportion of sample in each size class.

$H = 145.48$, $p < 0.001$, Fig. 10) and mass (Kruskal Wallis: $H = 103.07$, $p < 0.001$, Fig. 10). Non-parametric multi-comparisons tests (Zar, 1984) revealed that the 1970's data were significantly different from both the 1980's and 1990's data, but the 1980's data did not differ significantly from the 1990's data set in either TL or mass analyses. Therefore, I combined the 1980's data and the 1990's data as a "recent" data set for comparisons with the historical data set. This combination made qualitative comparisons across rivers easier. The size class distributions were not analyzed statistically for comparisons among the three decades. Qualitatively, the size distribution of the 1970's sample is normal, while those of the 1980's and 1990's are skewed toward decreased numbers of small animals (Fig. 11).

I sampled 32 hellbenders in 1998; two had legible brands from 1972 and 1988. The total number of recent hellbenders was 177. The mean length of recent individuals was greater than that of 1225 historical individuals (Mann-Whitney U-test: $W = 798610.5$, $p < 0.0001$, Fig. 12). The mean mass of 118 recent individuals also was greater than the mean mass of 855 historical individuals (Mann-Whitney U-test: $W = 387357.5$, $p < 0.0001$, Fig. 12). The size class distributions (recent vs. historical) were significantly different with relatively fewer individuals in the smaller size classes (Kolmogorov-Smirnov: $D = 0.5275$, $p < 0.0001$, Fig. 13). Males were in worse condition in recent years than historically (Mann-Whitney U-test: $W = 6956.0$, $p = 0.02$, Fig. 14).

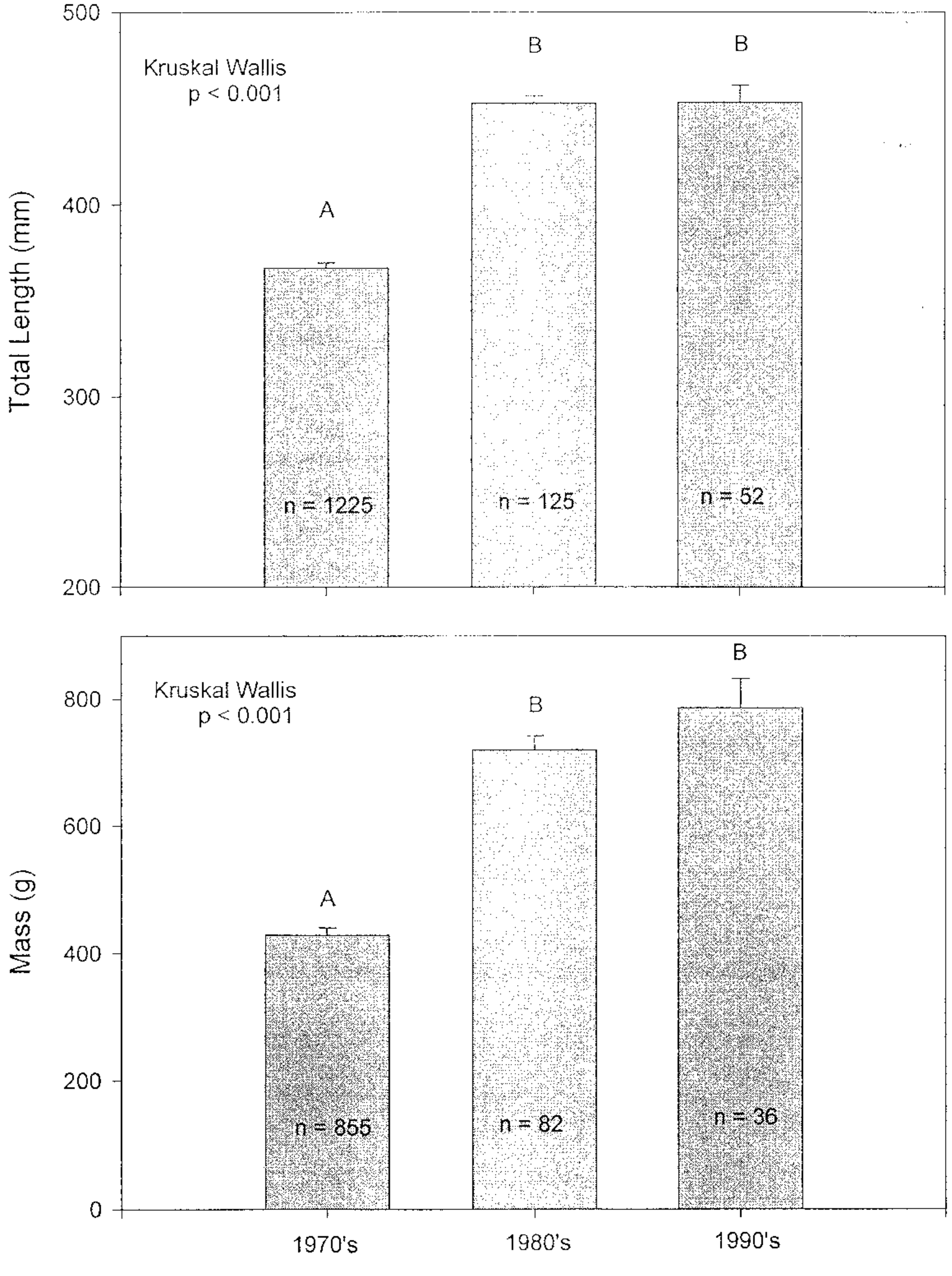

Fig 10: Comparison of mean total lengths and masses of hellbenders in the Niangua River from samples taken in the 1970's, 1980's, and 1990's. 1970's data are from 1971, 1972, 1973, and 1974. 1980's data are from 1979, 1980, 1986, 1988, and 1989. 1990's data are from 1990, 1991, 1992, 1993, 1994, 1997, and 1998. Bars show means ±1 SE.

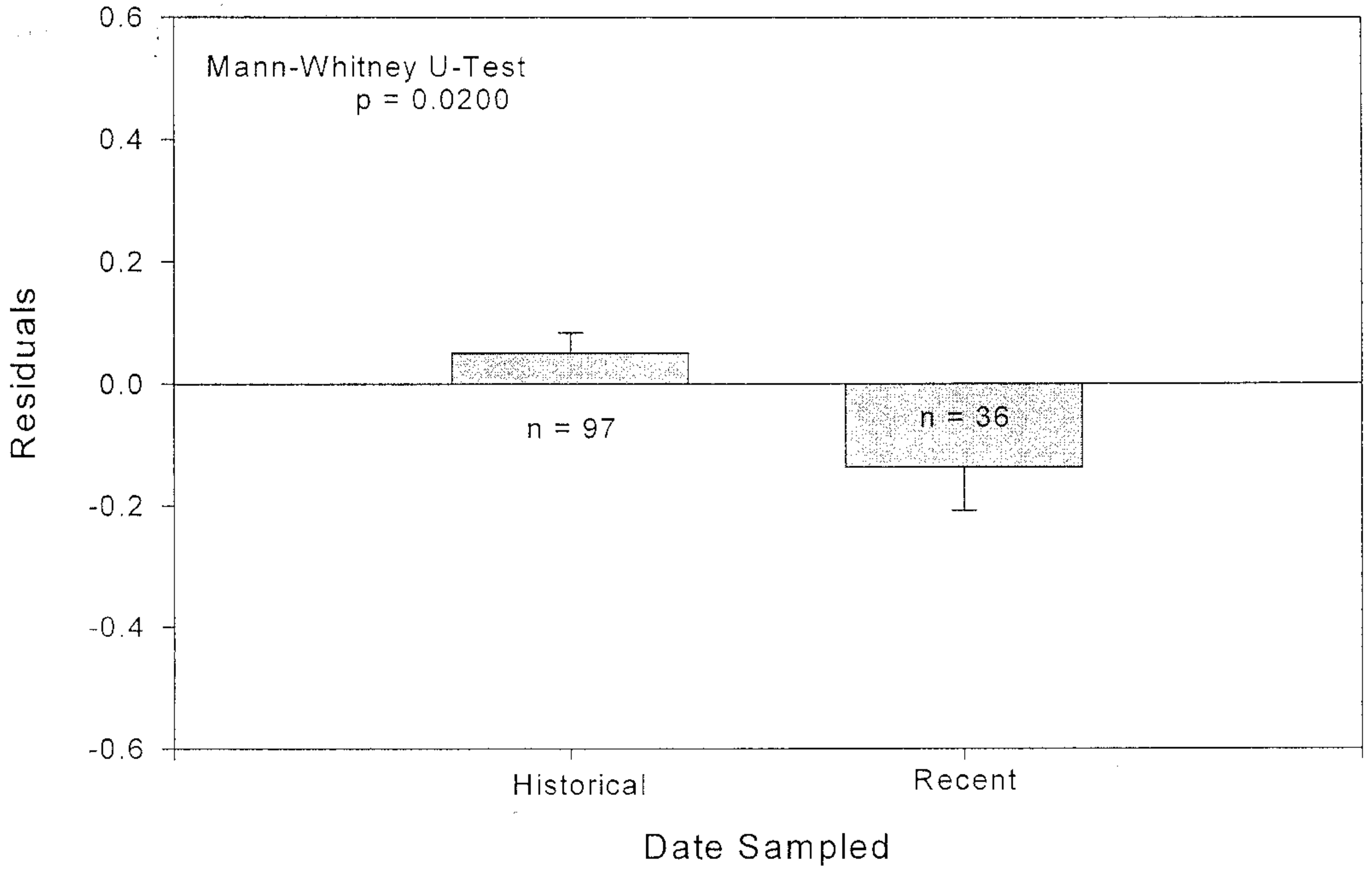

Fig 14: Comparison of body condition residuals of male hellbenders in the Niangua River from historical and 1998 samples. Historical samples were taken in 1978, 1980, 1981, and 1982. Recent Samples were taken in 1980, 1988, 1990, 1991, 1992, 1993, 1994, 1997, and 1998. Bars show means ±1 SE.

DISCUSSION

Historical Versus Recent Densities

Timing of the apparent declines in hellbender numbers (late 1970's to 1980's) agrees with other reports of amphibian declines beginning in the 1970's (Barinaga, 1990; Blaustein and Wake, 1990). This trend must be interpreted cautiously as the sampling days are not evenly distributed among years and the number of person-hours are not equal among days. However, the apparent declines in numbers are consistent in terms of both total numbers captured and numbers of individuals captured per day. There is no single factor clearly responsible for the apparent declines. Habitat destruction, such as damming, channeling and polluting of streams has been suggested as the most likely factor (Nickerson and Mays, 1973; Smith and Minton, 1957; Williams et al., 1981). R. F. Wilkinson (pers. comm.), who participated in both historical and 1998 censuses, noted some reduction in suitable habitat. However, I also found several areas of "good" habitat containing no hellbenders.

The apparent declines in numbers also could be explained by non-environmental factors. One possibility is that the sampling technique may have been inefficient and missed many individuals. Williams et al. (1981) found visual surveys and hand sampling underestimated hellbender populations in riffles in Pennsylvania; they suggested that electroshocking would be a less biased approach. However, I used the same technique that was used during the previous studies in these rivers (Nickerson and Mays, 1973; Peterson et al., 1988; Taber et al., 1975), and at least one historical study (Taber et al., 1975) did not use masks to aid visibility. So a bias in my sampling technique seems an

Brandon, R. A., and S. R. Ballard. 1994. *Cryptobranchus alleganiensis* (hellbender). Herpetological Review 25:31.

Burton, T. M., and G. E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook experimental forest, New Hampshire. Copeia 1975:541-546.

Carey, C. 1993. Hypothesis concerning the causes of the disappearance of the boreal toads from the mountains of Colorado. Conservation Biology 7:355-362.

Coatney, C. E., Jr. 1982. Home range and nocturnal activity of the Ozark hellbender. Master's thesis, Southwest Missouri State University, Springfield.

Delis, P. R., H. R. Mushinsky, and E. D. McCoy. 1996. Decline of some west-central Florida anuran populations in response to habitat degradation. Biodiversity and Conservation 5:1579-1595.

Duellman, W. E., and L. Trueb. 1994. Biology of Amphibians. Johns Hopkins University Press. Baltimore, Maryland.

Fauth, J. E., B. W. Buchanan, S. E. Wise, S. M. Welter, and M. J. Komoroski. 1996. *Cryptobranchus alleganiensis alleganiensis* (hellbender) coloration. Herpetological Review 27:135.

unlikely source for the observed order of magnitude decline in numbers of captures. A second possibility is that the apparent decline is the result of a habitat shift. Hellbenders can make use of both sheet rock and ledge rock for cover (R. F. Wilkinson, pers. comm.). I could not sample potential areas of either cover type with the "rock-flipping" technique. Hellbenders also may be making more extensive use of deep pools and holes in mud banks; I did not sample either in more than a cursory manner as they were believed to be less preferred habitats (Fobes, 1995). Finally, the apparent declines may be an artifact of sampling error. Observed fluctuations in number occurring in intervals shorter than the mean generation time of the organism may not represent changes in the population (Hairston and Wiley, 1993). Hellbenders are long-lived and I sampled individuals that still bore brands 10 to 28 years old. It is possible that my study represents natural population fluctuations (Pechmann et al., 1991).

Body Size

In all rivers hellbenders were larger (both longer and more massive) on average in 1998 than historically. This increase in average size is not due to an overall increase in size; the longest 1998 individuals were similar in size to the longest historical individuals. In the Niangua River, the largest 1998 individuals actually were smaller than the largest historical individuals. The increase in average size appears to be due to the loss of one or more of the smaller size classes. This shift in size distribution may be explained by several hypotheses. First, there could be reduced recruitment in the rivers. Hellbenders could be failing to produce eggs or the eggs could be failing to hatch. Topping and Ingersol (1981) found that hellbenders have a large reproductive potential based on numbers of eggs produced and deposited, and I caught numerous females in 1998 that had swollen abdomens, presumably with eggs. However, Peterson et al. (1988) captured only one larval hellbender and I captured none. Second, individuals may experience reduced survivorship at some critical size or stage (e.g., larvae). Finally, a single catastrophic event, such as the floods of 1993, could have killed one or more entire cohorts resulting in lost size classes. Taber et al. (1975) found a similar, less drastic shift in size distribution which was attributed to displacement of younger animals by a period of high water flow; no loss of size classes were reported. In the Niangua River, this shift in size distribution appears to have occurred in the late 1970's, so it is unlikely that the 1993 flood is the single causative factor.

Body Condition

Body conditions changed over time, but the direction of the change was not consistent. Males were in better condition in 1998 than historically in the Big Piney River, but in worse condition in 1998 than historically in the Niangua River. There was no difference in body conditions between 1998 and historical samples for the Gasconade River, but the low sample size reduced the statistical power to detect differences in the sample. An improved average body condition could be explained by competitive release with the apparent decline in numbers freeing up resources for the remaining individuals (e.g., Hairston, 1980). The decline in body condition in the Niangua River could be the additive result of increased human use of that river.

Fitch, F. W. 1947. A record of *Cryptobranchus alleganiensis*. Copeia 1947:210.

Fobes, T. M. 1995. Habitat analysis of the Ozark hellbender, *Cryptobranchus alleganiensis bishopi*, in Missouri. Master's thesis, Southwest Missouri State University, Springfield.

Griffiths, R., and T. Beebee. 1992. Decline and fall of the amphibians. New Scientist 134:25-29.

Guimond, R. W., and V. H. Hutchison. 1973. Aquatic respiration: An unusual strategy in the hellbender *Cryptobranchus alleganiensis alleganiensis* (Daudin). Science 182:1263-1265.

Guimond, R. W., and V. H. Hutchison. 1976. Gas exchange of the giant salamanders of North America. In Respiration of Amphibious Vertebrates. Ed. G. M. Hughes. Acedemic Press, New York.

Hairston, N. G. 1980. The experimental test of an analysis of field demonstrations: Competition in terrestrial salamanders. Ecology 61:817-826.

Hairston, N. G., Sr., and R. H. Wiley. 1993. No decline in salamander (Amphibia: Caudata) populations: A twenty –year study in the southern Appalachians. Brimleyana 18:59-64.

Human Influences

Humans could affect hellbender populations in several direct and indirect ways. Nickerson and Mays (1973) noted that hellbenders are susceptible to gigging and found many dead gigged specimens. Gigging season overlaps the fall breeding season of hellbenders. The number of campgrounds and canoe rentals has increased along the Niangua River (R. F. Wilkinson, pers. comm.), and heavy canoe traffic may take a toll on hellbenders (Nickerson and Mays, 1973) either directly or indirectly. Some of the hellbenders I captured had scars that may have been the result of a canoe hitting their cover rocks. Pollution from increased numbers of campgrounds along the river could have a negative impact, either directly by wastes harming the hellbenders or indirectly by wastes affecting the water temperature or crayfish populations. Unfortunately, no water chemistry/quality data are available from before the campgrounds were developed.

More work is needed to better elucidate the status of hellbenders in Missouri and to determine causes of the observed population changes. Although the data in this study span more than twenty years, they are short-term with respect to hellbender generation times and the variation I observed could represent natural population cycles (Pechmann et al., 1991). My censuses were diurnal, and nocturnal collection would identify individuals moving about during their active period. Nocturnal surveys also could allow animals that nest in inaccessible locations to be observed. Recruitment studies need to be performed to determine if hellbenders are successfully producing larvae. At least some females appeared to be gravid. However, I stopped censuses before the fall breeding season to avoid disturbing breeding activities, so I did not observe evidence of viable eggs or larvae. Electroshocking for larvae may be a good method to explore this little known portion of their life cycle. Public education might greatly enhance the hellbenders' status. For example, many fisherman "know" that hellbenders are poisonous and kill individuals unfortunate enough to take their bait (Nickerson and Mays, 1973).

Hillis R. E., and E. D. Bellis. 1971. Some aspects of the ecology of the hellbender, *Cryptobranchus alleganiensis alleganiensis*, in a Pennsylvania stream. Journal of Herpetology 5:121-126.

Licht, L. E., and K. P. Grant. 1997. The effects of ultraviolet radiation on the biology of amphibians. American Zoologist 37:137-145.

Merkle, D. A., S. I. Guttman, and M. A. Nickerson. 1977. Genetic uniformity throughout the range of the hellbender Cryptobranchus alleganiensis. Copeia 1977:549-553.

Nickerson, M. A., and C. E. Mays. 1973. The Hellbender: North American "Giant Salamanders". Milwaukee Public Museum, Milwaukee.

Nickerson, M. A., and M. D. Tohulka. 1986. The nests and nesting site selection by Ozark hellbenders, *Cryptobranchus alleganiensis bishopi* Grobman. Transactions of the Kansas Academy of Science 89:66-69.

Pechmann, J. H. K., and H. M. Wilbur. 1994. Putting declining amphibian populations in perspective: Natural fluctuations and human impacts. Herpetologica 50:65-84.

LITERATURE CITED

Barinaga, M. 1990. Where have all the froggies gone? Science 247:1033-1034.

Bishop, S. C. 1941. The salamanders of New York. New York State Museum Bulletin. No. 324. New York.

Blaustein, A. R., and D. B. Wake. 1990. Declining amphibian populations: A global phenomenon? Trends in Ecology and Evolution 5:203-204.

_____________, D. B. Wake, and W. P. Sousa. 1994a. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology 8:60-71.

_____________, P. D. Hoffmann, D. G. Hokit, J. M. Kiesecker, S. C. Walls, and J. B. Hays. 1994b. UV repair and resistance to solar UV-B in amphibian eggs: A link to population declines? Proceedings of the National Academy of Science, USA 91:1791-1795.

_____________, B. Edmond, J. M. Kiesecker, J. J. Beatty, and D. G. Hokit. 1995. Ambient ultraviolet radiation causes mortality in salamander eggs. Ecological Applications 5:740-743.

Pechmann, J. H. K., D. E. Scott, R. D. Semlitsch, J. P. Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892-895.

Peterson, C. L. 1979. Age and Growth of the Ozark Hellbender. Master's thesis, Southwest Missouri State University, Springfield.

____________. Personal Communication. 1998.

____________. 1987. Movement and catchability of the hellbender, *Cryptobranchus alleganiensis*. Journal of Herpetology 21:197-204.

____________, and R. F. Wilkinson. 1996. Home range size of the hellbender (*Cryptobranchus alleganiensis*) in Missouri. Herpetological Review 27:126-127.

____________, J. W. Reed, and R. F. Wilkinson. 1989. Seasonal food habits of *Cryptobranchus alleganiensis* (Caudata: Cryptobranchidae). The Southwestern Naturalist 34:438-441.

____________, R. F. Wilkinson, M. S. Topping, and D. E. Metter. 1983. Age and growth of the Ozark hellbender (*Cryptobranchus alleganiensis bishopi*). Copeia 1983:225-231.

__________, D. E. Metter, B. T. Miller, R. F. Wilkinson, and M. S. Topping. 1988. Demography of the hellbender *Cryptobranchus alleganiensis* in the Ozarks. The American Midland Naturalist 119:291-303.

Phillips, K. 1990. Where have all the frogs and toads gone? Bioscience 40:422-424.

Pounds, J. A., M. P. Fogden, J. M. Savage, and G. C. Gorman. 1997. Tests of null models for amphibian declines on a tropical mountain. Conservation Biology 11:1307-1322.

Smith B. G. 1907. The life history and habits of *Cryptobranchus allegheniensis*. Biological Bulletin 13:5-39.

Smith P. W., and S. A. Minton, Jr. 1957. A distributional summary of the herpetofauna of Indiana and Illinois. American Midland Naturalist 58:341-351.

Sokal, R. R., and F. J. Rohlf. 1995. Biometry, 3rd ed. W. H. Freeman and Company, New York.

Soule, N., and A. J. Lindberg. 1994. The use of leverage to facilitate the search for the hellbender. Herpetological Review 25:16.

Taber, C. A., R. F. Wilkinson, and M. S. Topping. 1975. Age and growth of hellbenders in the Niangua River, Missouri. Copeia 1975:633-636.

Topping, M. S., and C. A. Ingersol. 1981. Fecundity in the hellbender, *Cryptobranchus alleganiensis*. Copeia 1981:873-876.

Trenerry, M. P., W. F. Laurance, and K. R. McDonald. 1994. Further evidence for the precipitous decline of endemic rainforest frogs in tropical Australia. Pacific Conservation Biology 1:150-153.

Wake, D. B. 1991. Declining amphibian populations. Science 253:860.

Walls, S. C., A. R. Blaustein, and J. J. Beatty. 1992. Amphibian biodiversity of the Pacific Northwest with special reference to old growth stands. The Northwest Environmental Journal 8:53-69.

Wiggs, J. N. 1976. Food habits, starvation, and growth in the hellbender, *Cryptobranchus alleganiensis*. Master's thesis, Southwest Missouri State University, Springfield.

Wilkinson, R. F., Jr. Personal Communication. 1998.

Williams, R. D., J. E. Gates, C. H. Hocutt, and G. J. Taylor. 1981. The hellbender: A non-game species in need of management. Wildlife Society Bulletin 9:94-100.

Wyman, R. L. 1990. What's happening to the amphibians? Conservation Biology 4:350-352.

Zarr, J. H. 1984. Biostatisical Analysis. 2nd ed. Prentice-Hall, Englewood Cliffs, New Jersey.